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WORKSHOP ON PALEOCLIMATIC TRANSFER
FUNCTIONS, HELD AT UNIVERSITY OF
WISCONSIN-MADISON, ON APRIL 3, 1974

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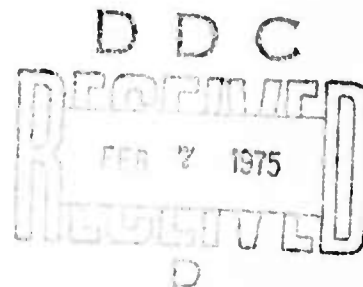
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The workshop brought together about 50 researchers who use statistical transfer functions to reconstruct climatic series from surrogates of climate. The purpose was to provide a free forum for exchange of information. Discussion centered on the following topics: (1) Transfer function types, i.e., statistics involved in the development of each. The features of each of the various types were emphasized. (2) Major limitations to all transfer functions, e.g., no modern analogues for conditions at some time in the past, grid size of modern sample array to adequately (over)

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describe the past conditions; (3) calibration of the transfer function, i.e.,
verification of the climatic reconstructions. (4) Peculiar porblems of
and insights gained by the various interest groups, e.g., tree-ring analysts,
palynologists, deep-sea core analysts.

The workshop on paleoclimatic transfer functions was convened at
Union South on the University of Wisconsin-Madison campus on April
3, 1974. A group of about fifty scientists (list of attendees attached)
came together for the three day meeting. Invited participants in-
cluded people who have been using statistical transfer functions for
past climatic reconstructions and some who are planning to use them.
Transfer functions have typically been developed from relationships
between one of three climatic surrogates and climate itself. The
surrogates fall under the three general categories: tree-rings,
pollen cores and deep sea cores. The statistics were often developed
independently of each other, and communication between the researchers
was difficult because they were widely separated in space and specialty.
This workshop provided an open forum for this diverse group of sci-
entists using a common tool, to group together and exchange information
on transfer functions.

ORGANIZATION

The first day consisted of a series of informal presentations
by various participants. The purpose was to acquaint each other with
the "state of the art" as used by the various contributors. The
first evening and the second day were used by four subgroups to
convene--each with a specific task to discuss. Reports and suggestions
from the subgroups were exchanged on the third day.

GENERAL SESSION

John Imbrie from Brown University introduced and summarized the work of the CLIMAP group, i.e., reconstructing sea surface oceanography from deep sea core records using transfer functions for 18,000 yrs BP. The CLIMAP group possesses a rather large data base and chronologies of the order of 10^5 years. Imbrie emphasized that reconstructions from several sources are necessary to check for replication and verification, i.e., using independent records to reconstruct environments for similar times of the past. "Ground truth" can be established from independent climatic records, or environmental information obtained from other climatic surrogates. A data bank of such environmental information is being assembled and maintained for this purpose at the Center for Climatic Research, University of Wisconsin-Madison.

One problem is apparently common to all groups using transfer function reconstructions of the past. Accurate reconstructions require that the transfer function be developed from a modern areal array of data with variance equal to that of the past, i.e., analogues of the past must be present in the modern data. Most data bases of the present cannot fulfill this requirement since mid-latitude glacial conditions are nowhere present today. Continued efforts will be used in solving this problem. Appropriately, one of the sub-sessions of the conference dealt with this problem.

Hal Fritts from the University of Arizona's Laboratory of Tree-Ring Research discussed the various reconstructions which his group has attempted using tree-rings as the data base. They have used transfer functions to relate modern tree-rings and various response functions, e.g., temperature and precipitation, atmospheric pressure, runoff, fish catch and altitudinal migration of tree line in montane regions. They subsequently generated response functions from the past 10^3 yrs based on tree-rings. Pollen transfer functions were

broadly outlined by Reid Bryson from the University of Wisconsin-Madison. He spoke of the nature of pollen changes at times of climatic change. Although some pollen frequencies rapidly change from maximum to minimum or vice versa at times of climatic change, "transient" type pollens actually may peak at the time of disturbance or change. This suggests that perhaps not all pollen taxa need be used in any given transfer function, i.e., some taxa may be more sensitive to climatic change than others and therefore should be expected to explain large percentages of the total variance.

Tom Webb from Brown University discussed advantages and disadvantages of using pollen percentages over pollen influx. He suggested that more work is necessary to evaluate which data base may present the most meaningful result. He then introduced a topic which was much discussed throughout the meeting and continues as an unsolved problem: Which transfer function yields the most meaningful result from each of the various data bases?

Transfer functions are nothing more than an areal statistical relationship developed from a modern array of data. The modern array consists of climatic parameters and some response function to climate, e.g., pollen frequencies, tree-ring widths, or information from lake or ocean sediments. The statistics have varied from relatively simple multiple linear regression models to factor and canonical analyses. Though various techniques are available, some are typically used by a given researcher, though the reasons are not always straightforward nor clear to observers why one method may be "better" than another. This is particularly true in factor and canonical analysis when the higher order factors or canonicals are often deleted from the reconstruction model. If all components of a multiple regression, factor or canonical analysis are used in the reconstruction, the three results are identical. However, when higher order components of any of the techniques are deleted from the reconstruction model, the results differ because the method whereby variables are "selected" for each

component differ from one statistic to another. The selection of the statistic, therefore, in part, determines the reconstruction. Discussion of the statistical methods available continued throughout the second day in one of the sub-groups described below.

Though some individual speakers have been named in this report, one should not conclude that they were the only contributors. Indeed, though they began each of the presentations, an open exchange soon evolved.

GROUP DISCUSSIONS

The evening of the first day and the entire second day were devoted to relatively small groups who discussed various problems of the transfer function method. This discussion of the second day was reported to the whole group on the third and closing day of the conference.

I. "No-Analogues" Section.

One of the groups was primarily concerned with reconstruction problems which arise because no climates analogous to late-glacial time can be found today. Therefore, the transfer function generates a late-glacial climate which is beyond the variance of the modern data sample. This problem cannot be solved by simply using more data, since mid-latitude glacial climates do not at present exist. On the other hand, there are areas where insufficient modern data exist, namely deep sea cores from the northwestern limb of the Atlantic Ocean, pollen from extreme northern North America and southern United States, and tree chronologies of a millenium or longer from other than the southwestern part of United States or northern Europe.

II.   Pollen Section (Report Submitted by T. Webb III).

A second group consisted of palynologists and others who work
with pollen data in climatic reconstructions. Their discussion
identified geographic regions and time scales to which quantitatively
derived transfer functions can be applied. These areas were:
(1) Holocene pollen profiles from N.W. Europe (H.J.B. Birks), (2) long
pollen profiles covering the last 100,000 years (T.A. Wijmstra and
D.P. Adam), and (3) pollen profiles from annually laminated sediments
(A. Swain and J. Pollack).

An initial discussion identified several general problems in
attempting to reconstruct quantitative climate estimates from fossil
pollen using transfer functions. These problems were: (1) human
disturbance a source of distortion in samples of modern pollen;
(2) the lack of adequate modern climate or vegetation records in
certain areas (e.g., mountains) from which the transfer function is
derived; (3) taxonomic problems pollen grains only identified to
level of family or genus, and additional problem that some families
(e.g., grass) or genera (e.g., oak or pine) have wide ecological
tolerances; (4) percentage problem pollen data recorded as percentages
of sums rather than pollen influx, (5) peat vs. lake sediment problem:
bog sediments may systematically accumulate different pollen spectra
from the spectra derived from lake sediments; (6) lake-development
problem: how does one cope with the evolution of a lake to a marsh
or bog; (7) validation problem: what independent records of climate
are available, and what constitutes a valid calibration data set;
(8) pollen sum problem: how does one differentiate between "sensitive'
and 'insensitive' pollen types (9) special no-analogue problem: how
to handle the situation when all species are present because of dif-
ferential migration rates. (10) local vs. regional problem: how do we
filter out the local from the regional pollen rain, can application of
principal components analysis down-core help; and (11) spatial character

of transfer function, i.e., must transfer functions to be used with annual or decadal varve pollen data be derived from a more dense regional array of surface pollen than a several-thousand year long core?

PROJECTED WORK:

A. Birks: Possible calibration of European Holocene records.

1. Begin constructing isopoll maps for 5000 YBP pollen in Britain (i.e., presettlement pollen), and compare these maps with modern distributions of the pollen and with the land form features.

2. Begin collecting modern surface pollen samples in Finland with an aim of calculating transfer functions. Plan to compare climatic estimates with the estimated curve of paleotemperatures from Denmark.

3. Compare differences in the pollen rain sample in peat vs. lake sediments.

4. Look for other sources of data to establish if the migration of spruce into Finnoscandia was climatically induced.

B. Wijmstra: Calibration of the Macedonian pollen core with 100,000 years of record.

C. Adam: Calibration of clear lake core from northern California.

D. Swain and Pollack: Calibration of short term pollen changes
    from present to 1000 A.D. in Hell's Kitchen Lake, north-central
    Wisconsin.

    Data array of 60 to 200 modern samples from a 200 km
or 600 km radius about the site was used. Because the
analogue for temporal pollen changes is developed from
spatial pollen changes, small short-term changes in pollen
require a detailed pollen record from a relatively small
spatial domain. On this spatial scale however, soil dif-
ferences between sites affect the pollen data as much as
climatic differences. Differences attributable to human
disturbance or fires are also factors. Work is now pro-
ceeding to include information about the soils in the data
analysis and to develop the transfer functions on samples
of presettlement pollen for which climatic information is
available. We hope also to correlate pollen reconstruction
with tree ring records.

III. Algebraic Problems (Report submitted by T.J. Blasing)
      were discussed by a third group.

A. Covariance Adjustment Problem

    The main topic of discussion was the effect of including latitude
in the calibration of pollen-climate transfer functions. For example,
daylength, which is implicitly and conveniently specified by latitude,
may be an important contributing factor to a pollen assemblage, but
it may be "aliased" as, say, temperature and precipitation effects,
if latitude is not included in the calibration. This, in turn, may
have an adverse effect on the prediction of past climate.

However, while temperature, precipitation, and pollen types may vary at a given location, latitude is a constant (at least on this time scale). Latitude may be a variable in the spatial developed equations, but is constant in the prediction of past climate from temporal pollen profiles at a given location.

To deal with this problem it was suggested that the pollen data might be judiciously adjusted for latitude before calibration as, for examples, is done by

1. The dendroclimatologists, who remove growth trends from tree ring width data via curve fitting techniques before calibrating, or

2. The meteorologists, who adjust for the effects of topography by adjusting surface pressure to mean-sea-level before analysis.

The adjustment factor may be different for different latitudes of prediction.

B. Choice of Mathematical Techniques

Some discussion was given to a classification of the various statistical techniques which would presumably make it easier to interpret the maze of current techniques and their variations. Classification according to statistical properties, e.g., linear, non-linear; orthogonal, non-orthogonal; univariate, multivariate; etc , is obviously desirable. However, it was found difficult to formulate a basis for the classification since the relationships between the statistical properties and the limitations of the techniques were not always known in the context of our various types of data. Those who have worked with a particular technique could contribute their findings of the limitations or attributes of each technique to a central information bank. Eventually some generalization

might emerge concerning the effects of the properties cf each
technique on actual environmental data. These generalizations could
serve as an aid in

1. technique selection,
2. communication with statisticians as to what statistical
    properties need to be better understood or what sorts
    of models need to be invented.

The task of coordinating the information exchange was assumed by
Doug Clark (Meteorology Dept., University of Wisconsin-Madison).

The selection of techniques may be made on the basis of which
one does the best job of predicting independent data. Three methods
of approach were discussed.

1. Independent data in time. For example, calibrate in
    the 20th Century; test equations in the 19th Century.

2. Independent data in space. For example, calibrate in
    the North Atlantic; test equations in the South Atlantic.

3. Generate synthetic dependent and independent data.
    Generate the data so that it may contain difficulties
    which you expect to encounter. For example, let the
    independent data have different variance-covariance
    properties than the dependent data. Then assess how
    each of several available techniques hoids up in
    solving the synthetic problem. Exchanging the results
    of such experiments may be helpful in achieving goals
    A and B in the preceeding paragraph.

It was suggested that we emphasize basic, or "neutral"
techniques, i.e., mathematical methods, the properties of which are
better understood rather than employing variations of the basic
techniques or more sophisticated techniques which may "cloud" the
interpretation without contributing to the total analysis.

It was suggested that communication with statisticians would be helpful in dealing with the above questions, and that therefore, some statisticians should be invited to future conferences of this nature.

The point was made that if all variance in the data is retained, several techniques "collapse" to multiple regression. If, however, some variance is to be eliminated from calibration (noise) while other variance is to be retained (information), then the investigator may select that technique which retains and organizes that part of the variance relevant to the experiment (information).

C. Error Analysis

Since statistical predictions have associated error terms, it is important to have an objective way of assessing that error. The expected value of the error term can be computed from the dependent, or calibration data, or from the errors in the prediction of independent data if such data is available. Replicability of experiments was stressed. An example of the analysis of replicability which was mentioned was the analysis of variance of tree ring width samples as done by Fritts.

D. General

Attention to basics, such as the above material, was often stressed. It was pointed out that it may not be wise to assess the correctness of our results on the basis of previous findings. First, general acceptance of previous findings does not constitute proof-- they may be wrong ("A foolish consistency is the hobgoblin of small minds"--Emerson). Secondly, apparently contradictory results may both (all) be partially correct and may turn out to be complimentary when communicated in the context of a more general framework.

CONCLUSIONS

The conference succeeded in providing a forum for workers
from various locations and backgrounds to exchange information.
The various models of transfer functions were reviewed and thoroughly
discussed. Application of these models to various response functions
were summarized.

Additionally. areas of future work were defined by the discussion.
These include areas of insufficient surface samples, areas of few,
if any, long cores, and abilities and limitations of the various
transfer functions themselves.

The grant provided most of the travel cost to bring the group
together, as well as the total cost of housing and meals while in
Madison.